

STUDY OF REVOLUTIONARY EARTH SCIENCES ARCHITECTURE FOR ATMOSPHERIC CHEMISTRY, EARTH RADIATION BALANCE, AND GEOMAGNETISM MEASUREMENTS

RASC 2002 study science rationale.

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This RASC study identifies atmospheric chemistry, earth radiation balance and geomagnetism as science areas that “would benefit tremendously from long-duration, autonomously coordinated, *in-situ* measurements in the stratosphere (20-35 km altitude)”. In this brief report, I outline how research within those science areas relates to the goals of the NASA Earth Science Enterprise (ESE).

NASA’s ESE scientific goals are to determine (a) how the Earth is changing and (b) what consequences those changes will have for life on Earth. The scientific strategy to address these complex goals is laid out in five steps, or rather questions (see 1). Each major question has several sub-questions. In the following, I describe the relationship between the RASC science areas and the NASA ESE questions.

Atmospheric Chemistry.

Atmospheric chemistry research addresses several of the questions in NASA’s ESE Strategic Plan, namely:

How is the global earth system changing?

- How is stratospheric ozone changing, as the abundance of ozone-destroying chemicals decreases and new substitutes increases?

What are the primary causes of the earth system variability?

- What trends in atmospheric constituents and solar radiation are driving global climate?

How does the earth system respond to natural and human-induced changes?

- How do stratospheric trace constituents respond to change in climate and atmospheric composition?

How well can we predict future changes in the earth system?

- How well future atmospheric chemical impacts on ozone and climate can be predicted?

Ozone shields humans on the Earth’s surface from harmful Ultra Violet (UV) radiation by absorbing it. Concentrations of ozone in the atmosphere vary depending on the presence/absence of other chemicals. As is clear from the ESE questions listed above, measurements of ozone and ozone-destroying chemicals in the stratosphere are required to assess and to forecast their impact on global earth system change. Current space-based remote observations of ozone and ozone-destroying chemicals lack needed vertical resolution and continuity (needed: 100 – 500 m, satellites: several km) and current *in situ* balloon observations are infrequent (1 per year) and are short in duration (3-10 hours).

A global network of stratospheric platforms could provide the opportunity to make continuous, detailed vertical profile measurements of ozone and other atmospheric constituents over a long period of time, 1 year or more, and at unprecedented spatial and temporal scales. Such data would give us an unprecedented view of the evolving structure of the stratospheric trace gases and yield clear observations that are key to international treaty obligations.

Earth Radiation Balance.

Earth Radiation Balance research addresses the following question outlined in NASA ESE Strategic Plan:

What are the primary causes of the earth system variability?

- What trends in atmospheric constituents and solar radiation are driving global climate?

The thermal IR and solar radiative fluxes (that enter into earth radiation balance) are the primary drivers of the climate and global change. Currently these fluxes are retrieved (i.e. calculated) from LEO satellite measurements of radiances. (Flux counts all the thermal radiative energy entering a point from all directions immediately above the point. Radiance is the amount of energy being received from a specific direction.) These satellite radiance measurements must be converted to fluxes at the top of the atmosphere (TOA) to estimate the Earth's energy budget. Knowing the Earth's energy budget is necessary for predicting long-term climate variability, interannual and seasonal changes on different spatial scales and effects of natural disasters, such as floods, fires and volcanic eruptions. The conversion process introduces 4% uncertainties into flux estimation, which can be large enough to affect the interpretation of the measured data. For example, 4% error in long wave flux estimation corresponds to an error of about 10 Wm^{-2} . Even 1 Wm^{-2} change in radiative forcing is important for climate change, and variability of 4 Wm^{-2} could drive a major climatic change.

There is a growing controversy within the science community regarding the validity of satellite radiative flux data sets, and the long-reaching conclusions regarding global warming-cooling and cloud cover trends, that are based on analysis of those data sets. A global network of stratospheric platforms could provide the opportunity to make direct measurements of fluxes (from stratospheric altitudes) rather than radiances from a satellite, thereby eliminating the radiance-to-flux conversion error and provide a significantly better estimate of the earth radiation budget and also an alternative method to verify satellite observations. By making these measurements from a stratospheric location, scientists could provide conclusive answers to fundamental questions like “is the Earth warming up?” and “is global cloudiness increasing or decreasing?”

Geomagnetism

Geomagnetism research addresses the following questions outlined in NASA ESE Strategic Plan:

How is the global earth system changing?

- What are the motions of the earth and the earth's interior, and what information can be inferred about earth's internal processes?

What are the primary causes of the earth system variability?

- How is the earth's surface being transformed and how can such information be used to predict future changes?

Measurements of the Earth's magnetic field over various temporal and spatial scales offer an opportunity to study the Earth's interior and its motions by identifying sources of the field. Observations of magnetic field variations over long time scales (years) would help to detect magma displacements in the Earth mantle and potentially lead to forecasts of earthquake and volcanic eruptions. High-spatial-resolution measurements would allow investigators to distinguish magnetic sources in the crust with applications in geology, paleogeology, geophysics, oil and mineral exploration, and archeology.

Measuring the Earth's magnetic field from stratospheric altitudes offers several advantages over surface and satellite measurements. One of the biggest advantages of making magnetic field measurements from the stratosphere is that internal, crustal, and external components of the Earth's magnetic field could be easily differentiated.

In addition, even though surface measurements of the Earth's magnetic field are made around the world by magnetic observatories, they only cover a small fraction of the Earth's surface. Systematic observations are lacking over oceans, Antarctica, Africa, South America, Siberia, and elsewhere. Measurements from oceanic vessels are slow and expensive. Satellite measurements are noisy due to ionospheric influence and require very high instrument sensitivity due to low field strength at orbital altitudes. (Magnetic field strength decreases with the square of the distance). The high orbital speed of the satellites also reduces the spatial resolution of the measurements.

The above factors make magnetic field measurements from stratospheric altitudes very attractive. A global network of stratospheric platforms would bridge the gap between surface and satellite measurements; provide observations with high resolution and high signal-to-noise ratio; provide global and regional coverage; provide measurements over different time scales; and lead to development of three-dimensional maps of the Earth's magnetic field and its sources. By making these measurements from a stratospheric location, scientists could answer questions about Earth's geological past and future.

References

1. The questions and some additional information can found at <http://www.earth.nasa.gov/science/questions.html>